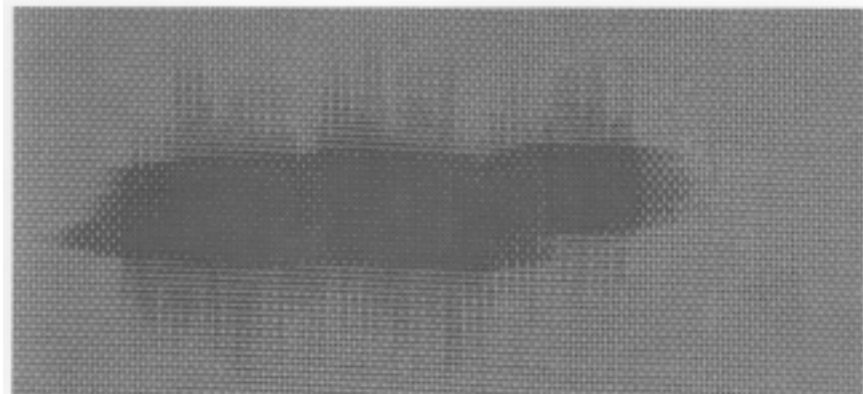




LOS ALAMOS NATIONAL LABORATORY 1997 R&D 100 AWARD WINNER
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The food stain shown here may be effectively removed through the innovative DryWash process. This process cleans with liquid CO₂ that is applied through high-pressure fluid jets.

Dry Wash™

*Los Alamos National Laboratory,
Hughes Environmental Systems, Inc.,
and Global Technologies, LLC*

From industrial laundries that service military installations to retail dry cleaners that cater to the public, the garment-cleaning industry affects billions of people and generates nearly \$20 billion in worldwide revenue each year. Unfortunately, the most commonly used dry-cleaning solvent, a chlorinated organic liquid known as perchloroethylene (perc), poses serious health and environmental hazards, and the costs of environmental compliance for perc have skyrocketed to the point that many cleaners cannot afford to operate. As a result, the dry-cleaning industry is searching for a viable alternative.

Los Alamos National Laboratory, Hughes Environmental Systems, Inc., and Global Technologies, LLC, have developed an innovative dry-cleaning process that offers such an alternative. This process, called DryWash™, cleans with liquid carbon dioxide (CO₂) that is applied through high-pressure fluid jets. As an odorless, nonflammable, nonhazardous solvent, CO₂ effectively removes oils, sweat, and dirt from a wide variety of fabrics. In addition to its environmental and performance benefits, DryWash also reduces dry-cleaning costs by lowering energy consumption, run times, and labor costs.

The Invention—Characteristics and Advantages

Carbon dioxide has been used in the past to clean a variety of electronic, mechanical, and optical equipment, but DryWash is the first process that uses CO₂ as a cleaning solvent for fabrics. In the DryWash system, liquid CO₂ at 54°F–58°F and 700 pounds per square inch—a pressure comparable to that used for soft-drink units at restaurants—is pumped from a storage tank into the cleaning vessel, and a

recirculating loop is established.

During the cleaning cycle, the CO₂ must remove CO₂-soluble soil, water-soluble soil, and pigment soil (insoluble in both CO₂ and water). The CO₂-soluble soils, including body oils, dissolve in the nonpolar, liquid CO₂ and are carried from the cleaning vessel. The water-soluble soils, such as salts, are usually removed by agitation. The most difficult to remove are the pigment soils, which are chemically bound to garments or mechanically trapped between adjacent fibers of the fabric.

The design of the cleaning vessel makes DryWash particularly effective at removing pigment soils. The garments are held in a perforated basket inside a stationary cleaning vessel. To get mechanical action equivalent to that of the rotating basket found in conventional dry-cleaning equipment, DryWash uses a process called hydrodynamic agitation, in which nozzles located on the inside periphery of the basket spray high-speed jets of liquid CO₂. The jets create a vortex that causes the clothes to spin around inside the basket. As the outermost garments pass through the fluid jets, they momentarily stretch slightly, and once they have moved away from the jets, they relax to their original size. This stretch-relax cycle effectively dislodges particles. The layer of peripheral fluid immediately carries the dislodged particles out through the drain without penetrating the bulk of the load, minimizing the amount of soil that is redeposited on other garments.

At the end of the cleaning cycle, the liquid CO₂ drains from the cleaning vessel and is converted to a gas in the still. The dirt carried from the garments (the only waste generated in the DryWash process) collects at the bottom of the still, and the clean, gasified CO₂ is then recondensed for the next cycle. Because CO₂ has a low surface tension and evaporates rapidly, only a short, “cold” (54°F–58°F) drying cycle is necessary.

DryWash offers numerous benefits. It is

- Environmentally friendly—Carbon dioxide is a nonflammable, nontoxic, inexhaustible solvent that will not deplete the ozone or pollute the ground water. As a result, DryWash helps the dry-cleaning industry comply with federal and state environmental regulations because the process minimizes wastes and emissions.
- Effective—The DryWash process greatly reduces pigment-soil redeposition (graying), fading, and dye transfer. Because CO₂ is a gentle solvent, it can effectively clean



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materials that perc often damages, such as leathers, furs, and accessories with sequins. In addition, the low temperatures of DryWash's drying cycle minimize heat-set stains and wrinkles.

- **Efficient**—Because of its short drying cycle, the DryWash process is complete in half the time required for conventional dry-cleaning processes.

- **Inexpensive to operate**—At 15–40¢ per pound, CO₂ is a cheaper solvent than perc (\$5–\$7 per pound), and DryWash minimizes the costs of environmental compliance, such as hazardous waste disposal and new emissions-control equipment. In addition, DryWash dramatically reduces the need for costly finishing labor and nearly eliminates liability costs associated with damaged garments.

Applications

DryWash offers an efficient and environmentally friendly replacement for the hazardous dry-cleaning methods currently used. The process can be used to clean almost all types of fabric encountered in the drycleaning industry, including some that cannot be cleaned by current perc technology. DryWash's benefits have the potential to affect billions of people worldwide who rely on retail dry cleaners or industrial laundries at hotels, military installations, hospitals, nursing homes, and corporate facilities.

In the future, the DryWash system and fluid jets could be used by industries to wash dishes and to degrease and decontaminate machined parts. Eventually, small-scale versions of DryWash may be available for laundry or dishwashing in the home.

Craig M. V. Taylor, the Los Alamos principal investigator on the DryWash project, joined the Laboratory in 1987, where he is now the team leader for the Supercritical Fluids Facility in the Organic Chemistry Group. He will receive his Ph.D. in physical chemistry from the University of Utah in 1997. Currently, his research focuses on the physical properties of supercritical fluids as these properties pertain to cleaning, extraction, solubility, and material modification.

W. Dale Spall received his Ph.D. in analytical chemistry from the University of New Mexico in 1970 and joined Los Alamos in 1975. He worked in the Organic Analytical Chemistry Group from 1986 to 1995 and was the former principal investigator of the DryWash project. In 1995, he left the Laboratory to become the director of Isotag Research, where he currently oversees the development of chemical bar-coding methods and techniques for chemically tagging consumer products.

Jerome Barton has worked as a technician at Los Alamos for 21 years and is now the senior technician at the Supercritical Fluids Facility. His expertise lies in mechanics, practical designs, instrumentation, and electronics.

Leah D. Bustos holds a B.S. in biology and chemistry from the College of Santa Fe. She has worked as an organic analytical technician at the Laboratory since 1987.

Leisa B. Davenhall joined the Laboratory in 1993 and has worked as a technician in the Supercritical Fluids Facility since 1995. She is experienced in method development and technical experimentation in dense-phase gas research.

Dennis L. Hjeresen joined the Los Alamos technical staff in 1985 after receiving his Ph.D. in neurobiology from the Univer-



sity of Washington in 1984. He currently serves as the supercritical fluids program manager.

W. Kirk Hollis leads the headspace gas analysis team at Los Alamos. Hollis, a technical staff member who joined the Laboratory in 1993, holds a B.S. in chemistry from New Mexico Institute of Mining and Technology.

Matthew Roepcke began working at Los Alamos as a co-op student in 1996 during his Senior year at Pojoaque High School. He will attend new Mexico Highlands University in the fall of 1997.

L. Dale Sivils received his Ph.D. in analytical chemistry from the University of Missouri in 1995 and has worked as a technical staff member at Los Alamos since 1995. His current research interests include instrumentation development and studies of supercritical fluid properties.

Shown here are the LANL researchers on the DryWash process: (back row, left to right) Jerome Barton, W. Kirk Hollis, Dennis L. Hjeresen, Matthew Roepcke; (front row, left to right) Craig M. V. Taylor, Leisa B. Davenhall, Leah D. Bustos, and L. Dale Sivils. The former principal investigator of DryWash, W. Dale Spall, is not pictured.

For more information about DryWash, please contact the Civilian and Industrial Technology Program Office, Los Alamos National Laboratory, P.O. Box 1663, Mail Stop C331, Los Alamos, NM 87545. Telephone (505) 665-9090 Fax (505) 667-0603

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